A surface-electrode ion trap for quantum computation

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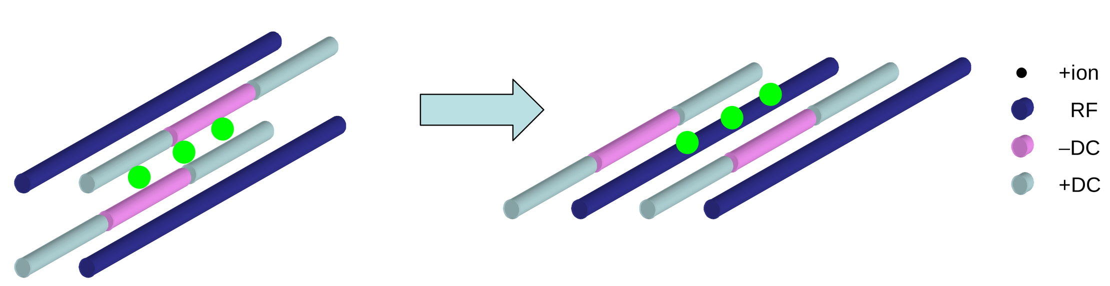
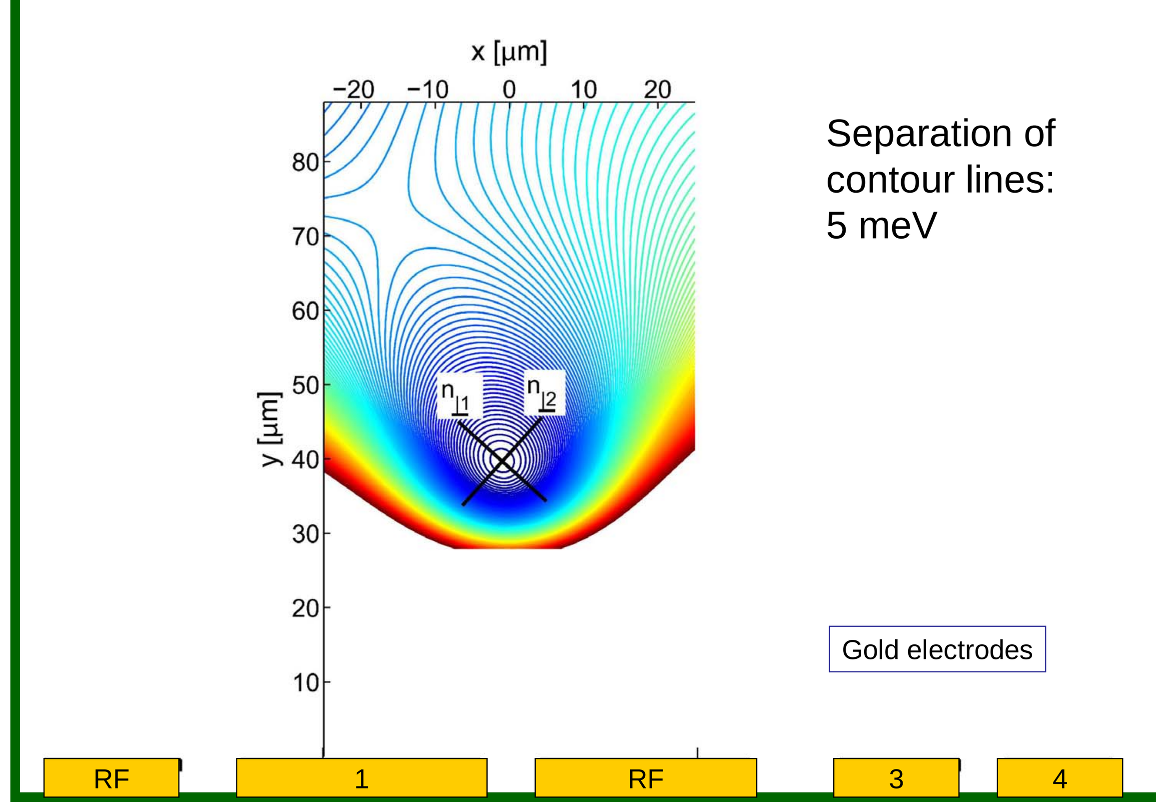
Idea : 3D → 2D linear Paul trap



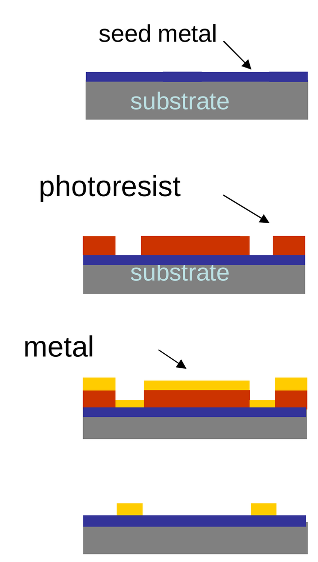
One approach : Gold electrodes directly on substrate - A "surface-electrode" trap

Pseudo-potential for our surface-electrode trap



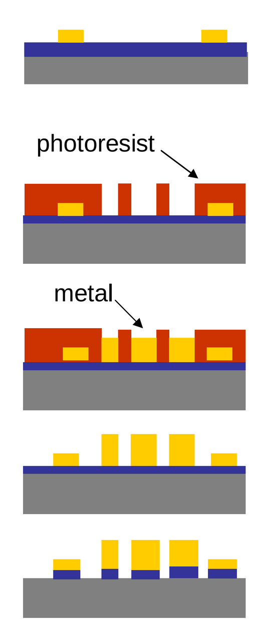
Fabrication methods

Resistors and leads : Liftoff



1. Put down seed layer for later electroplating (0.1 μm copper)
2. Define wire pattern in photo resist (holes in seed layer not shown)
3. Deposit metal (gold, 0.3 μm)
4. Remove resist

Electroplating for trap electrodes

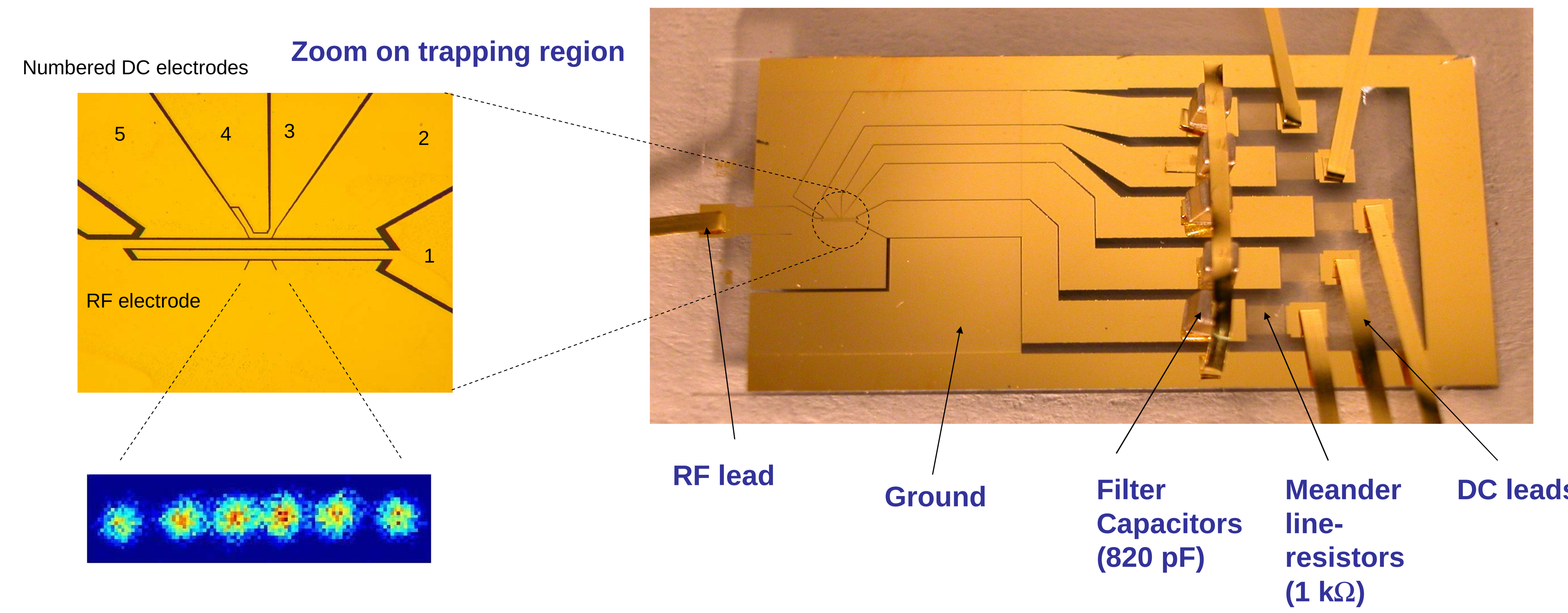


Starting point : seed layer, resistors and leads

5. Define wire pattern in thick photo resist
6. Electro plate ~6 μm Gold
7. Remove resist
8. Etch seed layer

Substrate material: fused quartz (low RF-loss)

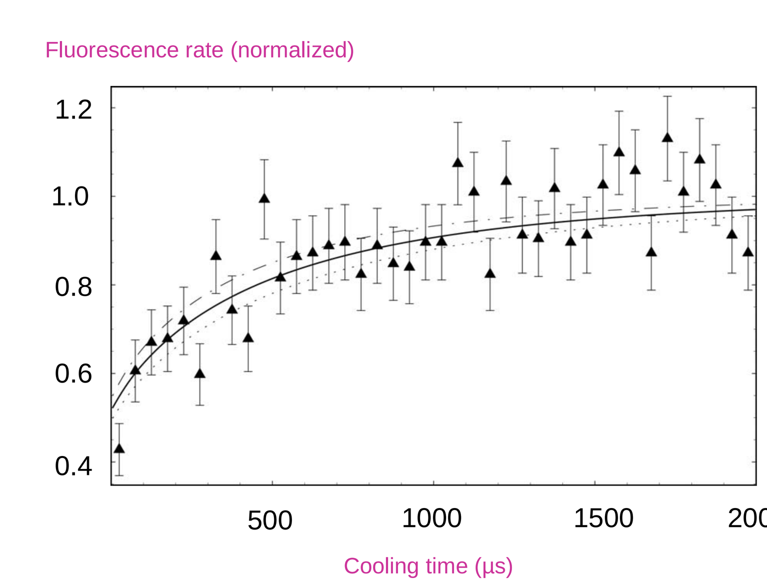
Pictures of surface-electrode ion trap (single zone)

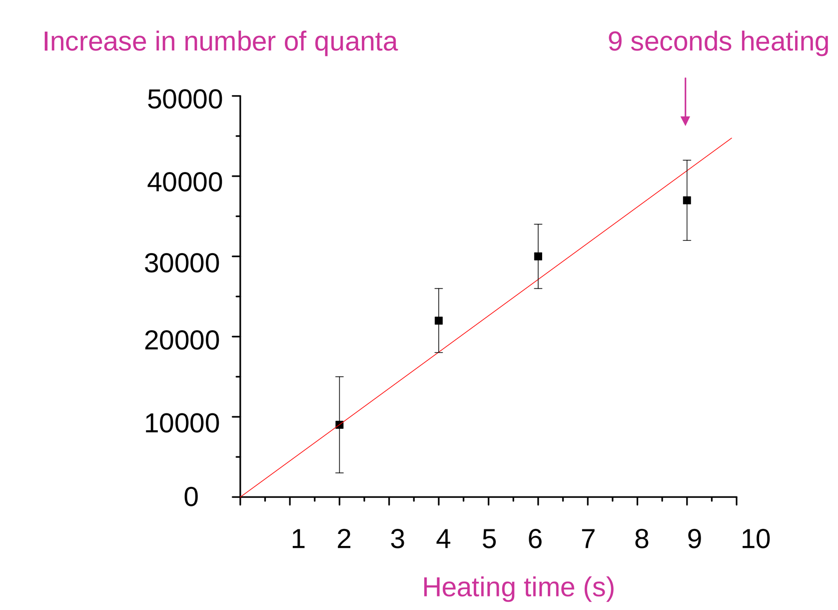


Heating rate

Observing fluorescence

- **Let ion heat (no laser cooling beam) for a certain amount of time (in our case 2, 4, 6 and 9 s.)**
- **For each heating time, re-cool ion while recording fluorescence during 2 ms (bins of 50 μs)**
- Due to Doppler broadening, fluorescence rate is initially decreases, and then increases when the cooling beam is applied.
- The shape of the curve can be modeled to extract a value for the increase in number of motional quanta over the given heating time.
- Note that the **model** does not include collisions (we assume a thermal energy distribution for the ion after heating). Therefore measured heating rate is a conservative estimate for noise-heating (we measure a heating rate due to both collisions and noise).



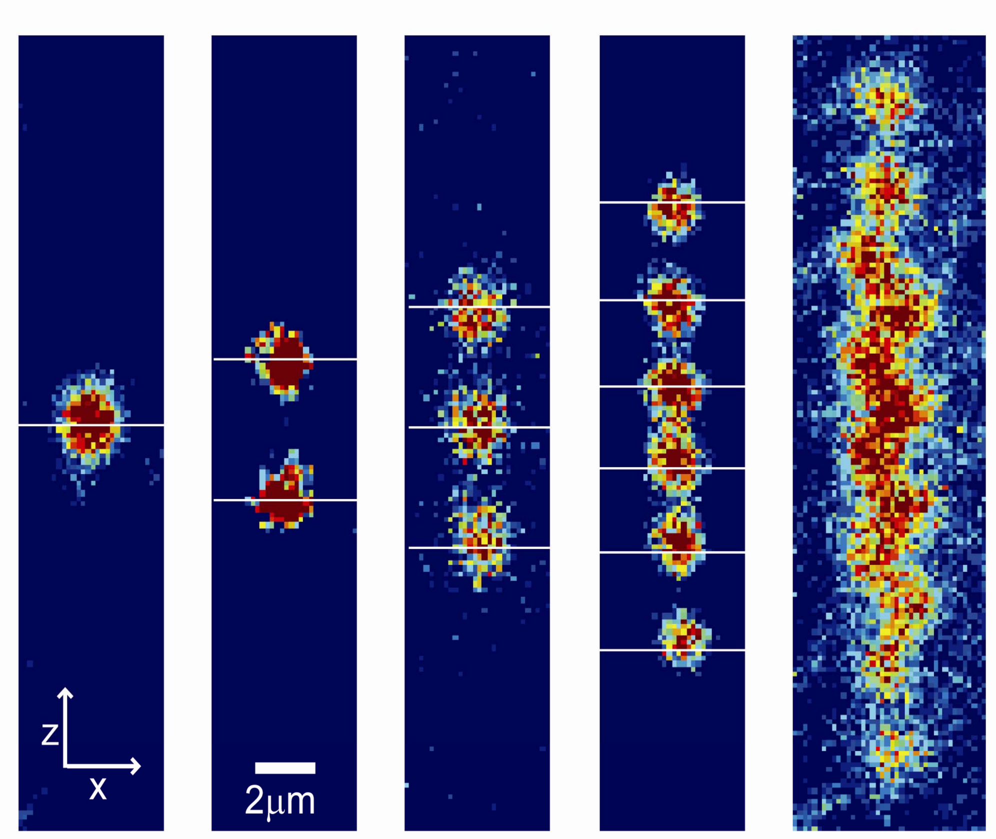


Fit gives 4.8 ± 0.4 quanta/ms

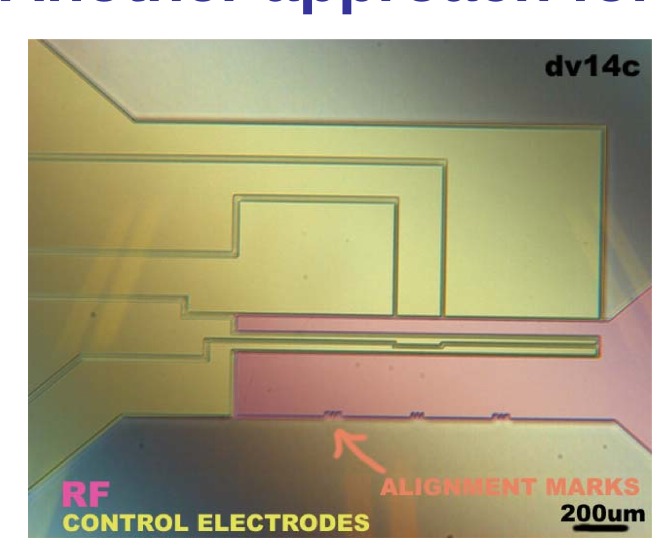
Escape time measurements in absence of cooling confirms result

Surface-electrode trap parameters

- Ions: $^{24}Mg^{+}$ (cooling/detection at 280 nm)
- Load via photo-ionization (2 photons at 285 nm)
- RF potential amplitude V_0~104 V
- DC voltages of the order of ~ 5 V
- RF drive frequency $\Omega/2\pi$ = 87 MHz
- Electrode width ~32 μm Gaps ~ 8 μm
- Trap axis height above surface 40 μm
- Transverse frequencies $\nu_{\perp 1}$= 16 MHz & $\nu_{\perp 2}$= 17 MHz
- Axial frequency $\nu_{\parallel}$ = 2.8 MHz
- Trap depth E_t=2100 K (180 meV)



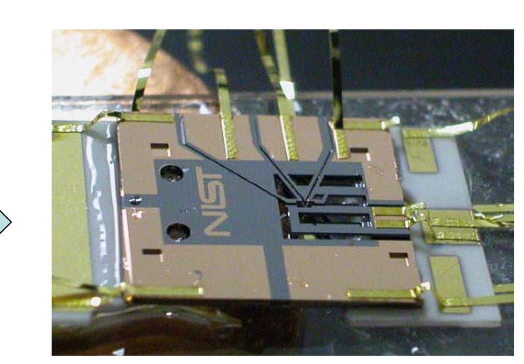
Another approach for a surface-electrode trap (ask J. Britton for details)



Boron-doped silicon

Surface-electrode design

Earlier demonstrated 2-layer design



Outlook

- Near future : Raman transition to measure heating rate near ground state.
- Then : fabricate surface traps with more complex structures (T- and X-junctions)
- And then : build a quantum computer !